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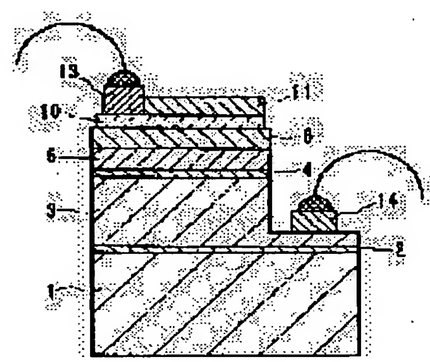
(54) NITRIDE SEMICONDUCTOR LIGHT EMITTING DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a light emitting device having an excellent external quantum efficiency by forming an electrode constituted of a first layer composed of a light transmitting metallic thin film and a second layer composed of a transparent conductive film containing an oxide on the surface of a p-type nitride semiconductor layer.
SOLUTION: After Pd is vapor-deposited on almost the entire surface of a p-type GaN layer as a first layer 10, a second layer 11 composed of ITO is vapor-deposited on the first layer 10 and a light transmitting electrode is formed by alloying parts of the first p-layer 10 and second layer 11 in a state where the constituents of layers 10 and 11 are united together. Consequently, the electrode side can be constituted as an emitted light observing surface, because an electric current can be spread uniformly throughout the player and the p-layer can transmit light. Therefore, the light emitted from an active layer can be fetched effectively. Moreover, since the electrode has an excellent ohmic property against the p-layer, in addition, a practical light emitting device having a low Vf can be obtained.



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CLAIMS

[Claim(s)]
[Claim 1] The nitride semi-conductor light emitting device characterized by forming the electrode with which p mold nitride semi-conductor layer consists of the first layer which becomes the front face of said p mold nitride semi-conductor layer from the metal thin film of translucency in the nitride semi-conductor light emitting device which it comes to form in the maximum front face, and the second layer which consists of transparence electric conduction film containing an oxide.
[Claim 2] The nitride semi-conductor light emitting device according to claim 1 characterized by the thickness of said first layer being 500A or less.
[Claim 3] The nitride semi-conductor light emitting device according to claim 1 or 2 characterized by consisting of the metal or alloy which was chosen from the group which said first layer becomes from nickel (nickel), platinum (Pt) palladium (Pd), a rhodium (Rh), a ruthenium (Ru), an osmium (Os), and iridium (Ir), and which contains a kind at least.
[Claim 4] A nitride semi-conductor light emitting device given in any 1 term of claim 1 characterized by consisting of an oxide which was chosen from the group which said second layer becomes from zinc (Zn), an indium (In), tin (Sn), and magnesium (Mg), and which contains a kind at least thru/or the claims 3.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the electrode of a light emitting device with which light emitting devices, such as LED to which it comes to carry out the laminating of the nitride semi-conductor (InXAlYGa1-X-YN, 0 <=X, 0<=Y, X+Y<=1), were started, especially p mold nitride semi-conductor layer was formed in the maximum front face.
[0002]
[Description of the Prior Art] Blue LED and green LED using current and a nitride semi-conductor (InXAlYGa1-X-YN, 0 <=X, 0<=Y, X+Y<=1) are put in practical use. The fundamental structure of such LED on a transparent insulating substrate For example, n mold nitride semi-conductor layer which consists of n mold AlYGa1-YN (0<=Y<=1) (henceforth n layers), The barrier layer which consists of InXGa1-XN (0< X<=1), and p mold nitride semi-conductor layer which consists of p mold AlZGa1-ZN (0<=Z<=1) (it is hereafter called p layers.) It has terrorism structure to the double by which the laminating was carried out to order. Since this LED cannot take out n electrode from a substrate side, it considers as the so-called flip chip format which takes out n electrode and p electrode from the same side side. A luminescence observation side side has many by which the electrode, i.e., p mold nitride semi-conductor layer, side is made the luminescence observation side, although the substrate also becomes a side someday a substrate and electrode side since it is transparent.
[0003] In order to take out luminescence of a barrier layer outside, the electrode which consists of a metal of translucency is prepared in p layers which become a luminescence observation side side. Moreover, we showed the light emitting device by which the metal electrode of translucency was prepared in the front face of p layers in JP,6-314822,A. However, in the metal electrode of the conventional translucency, the permeability of the electrode to blue and green light was bad, and was not what it can still be satisfied with external quantum efficiency of enough.
[0004] By the way, the electrode used for the light emitting device which consists of semiconductor materials, such as LED, needs to acquire the semiconductor material and desirable ohmic contact, also in order to reduce forward voltage. Also in said LED, desirable ohmic contact has been acquired with the electrode which contains Ti and aluminum in n layers, and the electrode which contains nickel and Au in p layers.
[0005] In addition, the tin oxide, indium oxide, and a zinc oxide are shown in JP,5-55631,A as an electrode material formed in a nitride semi-conductor. However, the ingredient shown in this official report is an electrode formed in the nitride semi-conductor of i (insulater) mold which doped acceptor impurity, and are not desirable ohmic **************** and the electrode formed in p layers. Moreover, although Ag, Au, Pt, Ir, Pd, Rh, etc. are stated to JP,5-315647,A as a desirable electrode formed in p layers, only Au electrode is prepared in i layers of the light emitting device of the metal-insulator-semiconductor structure instead of p mold in fact.
[0006]
[Problem(s) to be Solved by the Invention] Crystal growth is a very difficult ingredient and, as for p layers, it is more nearly actual than before that the physical properties are not yet solved well, either. Even if LED which has p-n junction is realized, the electrode formed in p layers also has many points which should still be improved, p more layers and concordance are good and the electrode material excellent in many properties is called for. Moreover, improvement in external quantum efficiency is desired in LED. Therefore, the place made into the purpose of this invention is by offering the new electrode of p layers useful as a light emitting device to realize the light emitting device excellent in external quantum efficiency.
[0007]
[Means for Solving the Problem] The light emitting device of this invention is characterized by forming the electrode with which p mold nitride semi-conductor layer consists of the first layer which becomes the front face of said p mold nitride semi-conductor layer from the metal thin film of translucency, and the second layer which consists of transparence electric conduction film containing an oxide in the nitride semi-conductor light emitting device which comes to carry out a laminating to the maximum front face.
[0008] Furthermore in the mode of this invention, it is characterized by the thickness of the first layer being 500A or less. If it is made thickness 500A or less, the translucency of the first layer will become very good.
[0009] Moreover, it is characterized by consisting of the metal or alloy which was chosen from the group which the first layer becomes from nickel (nickel), platinum (Pt) palladium (Pd), a rhodium (Rh), a ruthenium (Ru), an osmium (Os), and iridium (Ir) and which contains a kind at least. p type layer and desirable ohmic contact are acquired, and these metals or alloys can acquire still more desirable ohmic contact, if nickel and/or Pd are made into the side which touches p layers in the first layer also especially in it.
[0010] Moreover, in this invention, it is characterized by consisting of an oxide which was chosen from the group which the second layer becomes from zinc (Zn), an indium (In), tin (Sn), and magnesium (Mg) and which contains a kind at least. Specifically, ZnO, In 2O3, SnO2, ITO (oxide of In and Sn), MgO, etc. can be mentioned.

[0011] In the light emitting device of this invention, vacuum evaporationo, a spatter, etc. can use usual gaseous-phase film production equipment for forming the first layer and the second layer. The first layer is the metal thin film of translucency. For making a metal thin film into translucency, it is possible by control of the thickness of for example, a metal thin film. Although the thickness which becomes translucency changes also with metaled classes, it can be made into translucency by usually making it thickness 0.1 micrometers or less. It has the outstanding translucency with little absorption of luminescence of the first layer by making it still more preferably thickness 200A or less below 500A (0.05 micrometers) preferably. In addition, translucency means that an electrode penetrates the luminescence wavelength of a light emitting device, and does not necessarily mean colorless transparence.

[0012] As long as the first layer is the ingredient which can form the thin film of translucency with the metal used as the electrode of p layers, what kind of ingredient is sufficient, but especially the metal or alloy that was chosen from the group which consists of nickel, Pt, Pd, Rh, Ru, Os, and Ir and that contains a kind at least is useful, when p layers and desirable ohmic contact are acquired and the forward voltage of a light emitting device is lowered. near 360nm - 650nm of the light emitting device which will consist of a nitride semi-conductor if nickel and/or Pd are made into the side which touches p layers also especially in it — there is little absorption with a wavelength of 380nm - 560nm, and since it excels also in ohmic nature, it is desirably the most desirable. Moreover, it is good also considering this first pass as a laminated structure of said metal. If an electrode is behind processed by thermal annealing in the case of a laminated structure, an electrode material will be in the condition of having alloyed in complete harmony in the first pass.

[0013] The second layer is formed on the first layer and makes resistance of the whole electrode low. Therefore, let the second layer be the transparence electric conduction film containing an oxide. Although there are many classes of the transparence electric conduction film containing an oxide, it is desirable to form the low transparence electric conduction film of resistance containing oxides, such as Zn, In, Sn, Mg, etc. which are especially shown preferably by ZnO, In 2O3, SnO2, ITO (oxide of In and Sn), MgO, etc. Especially the thickness of the second layer which consists of this transparence electric conduction film cannot be limited, and can be formed by the thickness of several angstroms - several micrometers.

[0014] The light emitting device of this invention can create the crystal of a nitride semi-conductor by growth and carrying out a laminating on a substrate using vapor growth equipments, such as MOVPE (metal-organic chemical vapor deposition), HDVPE (halide vapor growth), MBE (molecular-beam vapor growth), and MOMBE (organic metal molecular-beam vapor growth). Although sapphire (aluminum 2O3), ZnO, a spinel (MgAl 2O4), SiC, Si, GaN, etc. are used for a substrate, generally sapphire and SiC are used in many cases. A laminating is carried out so that the laminating of the p layers may be carried out and p layers may become the maximum front face on n layers fundamentally as a laminated structure, and it considers as the structure which can form an electrode in p layers on this front face of the maximum. The light emitting device of the heterojunction which specifically has p-n junction and which passes and has terrorism structure and pin junction etc. is mentioned. The nitride semi-conductor of n mold can grow, if donor impurities, such as Si, germanium, and Se, are doped. On the other hand, the nitride semi-conductor of p mold can grow by doping acceptor impurity, such as II group elements, such as Mg and Zn, and C, in a nitride semi-conductor. For example, although there are some which show p mold property even if it does not carry out processing of what after growth when the nitride semi-conductor which doped acceptor impurity using the MOVPE method is grown up, by performing annealing processing above 400 degrees C comes to show still more desirable p mold property preferably. In addition, in p mold, it is the nitride semi-conductor which doped acceptor impurity, and the semi-conductor which resistivity shows 103 or less ohm-cm is said.

[0015]

[Function] Drawing 1 is a graph which shows the current potential property of the various electrodes formed in p layers. After forming concretely only the first layer described below on p layers, or after forming the first layer and second layer, the ohmic nature to p layers of the electrode is investigated by annealing above 400 degrees C, forming an electrode, and measuring the current potential property of the electrodes of the same class. Moreover, drawing 2 is a graph which shows the permeability of the translucency electrode shown in drawing 1 . The electrode is as follows.

[0016]

A: The translucency electrode which formed Pd in the first layer by 40A thickness.

B: The translucency electrode C which formed Rh in the first layer by 40A thickness : the translucency electrode which formed in the first layer by 10A, and formed ZnO in the second layer for Pd by 500A thickness.

D: The translucency electrode which formed in the first layer by 10A, and formed In 2O3 in the second layer for Pd by 500A thickness.

E: The translucency electrode which formed in the first layer by 60A, and formed Au in the second layer for nickel by 200A thickness.

[0017] As shown in drawing 1 , when Pd (A) is made into the side which touches p layers, it shows very good ohmic nature. In addition, the more the thickness of Pd becomes thin, the more the inclination of A line is in the inclination which becomes small. On the other hand, once, although Rh (B) shows ohmic nature, compared with other A, CDs, and E, contact resistance is large [Rh]. In addition, since the element of other platinum groups, such as Ru, Os, and Ir, showed the same inclination as B line, it is omitted. Next, the electrode (C) which formed Pd in the eye and formed ZnO in the bilayer eye further, and the electrode (D) which formed Pd in the eye and formed In 2O3 in the bilayer eye further show good ohmic contact. Since this inclination was the same also as ITO, SnO2, or MgO, it omits the second layer. Moreover, its permeability is bad although the electrode (E) which formed nickel in the eye and formed Au in the bilayer eye further shows good ohmic contact. This is described later. In addition, since the inclination as E lines for the electrode which formed nickel and Pt in the first pass eye about ohmic nature to be also the same was shown, it omits.

[0018] Moreover, although drawing 2 shows the permeability of each electrode, the electrode (E) containing conventional nickel-Au has the bad permeability applied to the purple which is the description of luminescence of a nitride semi-conductor light emitting device - a green field. On the other hand, since the permeability of the electrodes C and D concerning the light emitting device of this invention is very excellent compared with E, it can raise the external quantum efficiency of a light emitting device. Moreover, since the translucency electrode which becomes only a first pass eye from

elements, such as the elements Pt, Ru, Os, and Ir of other platinum groups, shows A, B line, and similar permeability, it is omitted.
[0019] In the light emitting device which uses p layers as the maximum front face, if the electrode formed in p layers does not interrupt luminescence, the external quantum efficiency of a light emitting device improves. Then, the external quantum efficiency of a light emitting device improves by forming in the front face of p layers the electrode which consists of the first layer which consists of a metal thin film of translucency with sufficient permeability, and the second layer which consists of transparence electric conduction film containing an oxide with sufficient permeability.
[0020] Furthermore, although the first layer as a good electrode of translucency can be formed as the thickness of the first layer is 500A or less, it is in the inclination for the seeds resistance to p layers of an electrode to become large, by making thickness of the first layer thin gradually. In this invention, it can prevent that the thickness of the electrode as the whole becomes thick and resistance becomes large by forming the second layer which is the transparent electric conduction film on the first layer. And since translucency has been maintained as the whole electrode, luminescence is taken out efficiently outside.
[0021] Furthermore, since p layers and desirable OMIKKU are obtained also in the condition of having made thickness thin by considering as the metal or alloy which was chosen from the group which becomes the first layer from nickel, Pt, Pd, Rh, Ru, Os, and Ir and which contains a kind at least, Vf of a light emitting device falls and the component excellent in luminous efficiency can be realized. Moreover, the permeability in the purple by which it is characterized - a green [a nitride semi-conductor light emitting device] wavelength region is good.
[0022] Moreover, even if the permeability in a purple - green wavelength region is good and makes thickness of the first layer thin further as mentioned above, since there is this second layer, the oxide thin film of the conductivity which contains a kind at least chosen from the group which becomes the second layer from Zn, In, Sn, and Mg has the advantage that resistance of an electrode does not go up.
[0023]
[Example] Hereafter, one example of the light emitting device of this invention is explained based on a drawing. Drawing 3 is the top view which looked at the light emitting device of this invention from the electrode side of p layers, and drawing 4 is the typical sectional view showing the structure at the time of the alternate long and short dash line shown in drawing cutting the light emitting device of drawing 3 .
[0024] The buffer layer 2 which consists of GaN on the silicon on sapphire 1 of 2 inch phi using a [example 1] MOVPE reactor 200A, The barrier layer 4 of the single quantum well structure which consists of 4 micrometers and non dope In0.2Ga0.8N n mold contact layer 3 which consists of an Si dope n mold GaN 30A, p mold contact layer 6 which consists of 0.2 micrometers and a Mg dope p mold GaN p mold cladding layer 5 which consists of Mg dope p mold aluminum0.1Ga0.9N is grown up in order by 0.5-micrometer thickness.
[0025] Furthermore, annealing of the wafer is carried out at 600 degrees C in nitrogen-gas-atmosphere mind into a reaction container, and 5 and 6 are further formed into low resistance. [p-layer] A wafer is picked out from a reaction container after annealing, the mask of a predetermined configuration is formed in the front face of the p mold GaN of the maximum upper layer, etching is performed from on a mask by the etching system, and as shown in drawing 2 , a part of n mold contact layer 3 is exposed.
[0026] Next, the mask on p layers is removed and Pd is mostly vapor-deposited as the first layer 10 on the whole surface by the p mold GaN layer [of the maximum upper layer] thickness which is 20A. The first layer after vacuum evaporationo had become translucency clearly, to silicon on sapphire 1, was transparent and has been observed. Thus, a current can be extended to homogeneity at p layer of the whole by [of p layers which exposed the first layer] forming in the whole surface mostly, and since it is moreover translucency, an electrode side is made with a luminescence observation side.
[0027] The pad electrode 13 containing Au and nickel for bondings is formed in the corner of the first layer by 2-micrometer thickness after the first layer 10 formation. In addition, this pad electrode 13 is not translucency.
[0028] The second layer 11 which consists of ITO on the first layer 10 is vapor-deposited by 500A thickness after pad electrode 13 formation.
[0029] After forming the pad electrode 13, the n electrode 14 which contains Ti and aluminum in n exposed layers is formed by 2-micrometer thickness, finally it heat-treats above 400 degrees C with an annealer, and an electrode is made to alloy. In addition, since the electrode of the translucency which consists of the first p-layer layer 10 and the second layer 11 by annealing is in the condition of having alloyed and harmonized completely, at drawing 1 , it does not dare indicate the electrode on the front face of the maximum to be the second layer 11, but a sign called 10+11 shows in the semantics of the first layer + second layer.
[0030] The wafer which formed the electrode in n mold contact layer 3 and the p layer contact layer 6 as mentioned above When cut in the shape of [of 350 micrometer angle] a chip, and paste up with a leadframe, wire bond of silicon-on-sapphire side 1 of the luminescence chip is carried out, mold is carried out with an epoxy resin and it considers as an LED component, it sets to If(forward current)20mA. It was 460nm in Vf(forward voltage)3.4V and luminescence wavelength, and the radiant power output was higher than LED of this structure which has p electrode of the translucency containing conventional nickel and conventional Au about 30%.
[0031] In the [example 2] example 1, when form in the first layer 10 by 20A, and In 2O3 was formed in the second layer 11 for nickel by 500A thickness and also the LED component was obtained like the example 1, in If20mA, the radiant power output was almost equivalent to the thing of an example 1 Vf3.5V.
[0032] In the [example 3] example 1, when carried out the 10A laminating of 10A and the nickel for Pd to the first layer 10, and SnO2 was used for the second layer 11 and also the LED component was obtained like the example 1, in If20mA, Vf3.4V and a radiant power output were also almost equivalent to the thing of an example 1.
[0033] In the [example 4] example 1, when carried out the 10A laminating of 10A and the Pt for Pd to the first layer 10, and ZnO was used for the second layer 11 and also the LED component was obtained like the example 1, in If20mA, Vf3.5V and a radiant power output were also almost equivalent to the thing of an example 1.
[0034] In the [example 5] example 1, when carried out the 10A laminating of 10A and the Rh for Pd to the first layer 10,

and MgO was used for the second layer 11 and also the LED component was obtained like the example 1, in If20mA, Vf3.5V and a radiant power output were also almost equivalent to the thing of an example 1.

[0035] In the [example 6] example 1, when carried out the 10A laminating of 10A and the Ru for Pd to the first layer 10, and In 2O3 was used for the second layer 11 and also the LED component was obtained like the example 1, in If20mA, Vf3.5V and a radiant power output were also almost equivalent to the thing of an example 1.

[0036] In the [example 7] example 1, when thickness of the first layer 10 was made into 200A and also the LED component was obtained like the example 1, although it was Vf3.4V in If20mA, since the translucency of the first layer was lost a little, the radiant power output declined about 20% compared with the thing of an example 1.

[0037]

[Effect of the Invention] As explained above, the light emitting device of this invention can be formed in the front face of p layers, and can take out luminescence of a barrier layer outside effectively. And since the electrode is excellent also in ohmic nature with p layers, Vf can realize a low practical light emitting device. When the light emitting device of this invention is used for LED devices, such as a full color LED display and LED signal and a traffic information display board, a low power can realize a bright device and the utility value on the industry is size.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Drawing showing the current potential property of the various electrodes formed in p layers.
[Drawing 2] Drawing showing the permeability to each wavelength of the various electrodes formed in p layers.
[Drawing 3] The top view showing the electrode configuration of the light emitting device concerning one example of this invention.
[Drawing 4] The type section Fig. showing the structure of the light emitting device of drawing 1
[Description of Notations]
1 .... Silicon on sapphire
2 .... Buffer layer
3 .... n mold contact layer
4 .... Barrier layer
5 .... p mold cladding layer
6 .... p mold contact layer
10 .... The first layer
11 .... The second layer
13 .... Pad electrode
14 .... n electrode

[Translation done.]

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(54)【発明の名称】　窒化物半導体発光素子

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(57)【特許請求の範囲】
【請求項１】　ｐ型窒化物半導体層が最表面に形成されてなる窒化物半導体発光素子において、前記ｐ型窒化物半導体層の表面に、透光性の金属薄膜よりなる第一の層と、酸化物を含む透明導電膜よりなる第二の層とからなる電極が形成されていることを特徴とする窒化物半導体発光素子。
【請求項２】　前記第一の層の膜厚が５００オングストローム以下であることを特徴とする請求項１に記載の窒化物半導体発光素子。
【請求項３】　前記第一の層がニッケル（Ｎｉ）、白金（Ｐｔ）パラジウム（Ｐｄ）、ロジウム（Ｒｈ）、ルテニウム（Ｒｕ）、オスミウム（Ｏｓ）、イリジウム（Ｉｒ）よりなる群から選択された少なくとも一種を含む金属または合金よりなることを特徴とする請求項１または請求項２に記載の窒化物半導体発光素子。

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【請求項４】　前記第二の層が亜鉛（Ｚｎ）、インジウム（Ｉｎ）、スズ（Ｓｎ）、マグネシウム（Ｍｇ）よりなる群から選択された少なくとも一種を含む酸化物よりなることを特徴とする請求項１乃至請求項３の内のいずれか一項に記載の窒化物半導体発光素子。
【発明の詳細な説明】
【０００１】
【産業上の利用分野】本発明は窒化物半導体（$In_XAl_YGa_{1-X-Y}N$、０≦X、０≦Y、X+Y≦１）が積層されてなるＬＥＤ等の発光素子に係り、特に最表面にｐ型窒化物半導体層が形成された発光素子の電極に関する。
【０００２】
【従来の技術】現在、窒化物半導体（$In_XAl_YGa_{1-X-Y}N$、０≦X、０≦Y、X+Y≦１）を用いた青色ＬＥ

Ｄ、緑色ＬＥＤが実用化されている。これらのＬＥＤの基本的な構造は、透明な絶縁性基板の上に例えばｎ型$Al_YGa_{1-Y}N$（$0≦Y≦1$）よりなるｎ型窒化物半導体層（以下、ｎ層という。）と、$In_XGa_{1-X}N$（$0<X≦1$）よりなる活性層と、ｐ型$Al_ZGa_{1-Z}N$（$0≦Z≦1$）よりなるｐ型窒化物半導体層（以下、ｐ層という。）とが順に積層されたダブルヘテロ構造を有している。このＬＥＤは基板側からｎ電極を取り出すことができないので、同一面側からｎ電極と、ｐ電極とを取り出す、いわゆるフリップチップ形式とされている。発光観測面側は基板が透明であるので、基板側、電極側いずれ側にもなるが、電極側、つまりｐ型窒化物半導体層側が発光観測面とされているものが多い。

【０００３】発光観測面側となるｐ層には、活性層の発光を外部に取り出すために透光性の金属よりなる電極が設けられている。また我々は特開平６－３１４８２２号公報において、ｐ層の表面に透光性の金属電極が設けられた発光素子を示した。しかしながら、従来の透光性の金属電極では、青色、緑色光に対する電極の透過率が悪く、外部量子効率では未だ十分満足できるものではなかった。

【０００４】ところで、ＬＥＤ等の半導体材料よりなる発光素子に使用される電極は、順方向電圧を低下させるためにも、その半導体材料と好ましいオーミック接触を得ている必要がある。前記ＬＥＤにおいても、ｎ層にはＴｉとＡｌを含む電極、ｐ層にはＮｉとＡｕを含む電極で好ましいオーミック接触を得ている。

【０００５】その他、窒化物半導体に形成する電極材料として、例えば特開平５－５５６３１号には酸化スズ、酸化インジウム、酸化亜鉛が示されている。しかしこの公報に示される材料はアクセプター不純物をドープしたｉ(insulater)型の窒化物半導体に形成する電極であって、好ましいオーミックは得られておらず、ｐ層に形成する電極ではない。また特開平５－３１５６４７号公報にはｐ層に形成する好ましい電極としてＡｇ、Ａｕ、Ｐｔ、Ｉｒ、Ｐｄ、Ｒｈ等が述べられているが、実際にはｐ型ではなくＭＩＳ構造の発光素子のｉ層にＡｕ電極しか設けられていない。

【０００６】

【発明が解決しようとする課題】ｐ層は従来より結晶成長が非常に難しい材料であり、その物性も未だ良く解明されていないのが現実である。ｐ－ｎ接合を有するＬＥＤが実現されてもｐ層に形成する電極には未だ改良すべき点も多く、さらにｐ層となじみが良く、数々の特性に優れた電極材料が求められている。またＬＥＤでは外部量子効率の向上が望まれている。従って本発明の目的とするところは、発光素子として有用なｐ層の新規な電極を提供することにより、外部量子効率に優れた発光素子を実現することにある。

【０００７】

【課題を解決するための手段】本発明の発光素子は、ｐ型窒化物半導体層が最表面に積層されてなる窒化物半導体発光素子において、前記ｐ型窒化物半導体層の表面に、透光性の金属薄膜よりなる第一の層と、酸化物を含む透明導電膜よりなる第二の層とからなる電極が形成されていることを特徴とする。

【０００８】さらに本発明の態様では、第一の層の膜厚が５００オングストローム以下であることを特徴とする。５００オングストローム以下の膜厚にすれば、第一の層の透光性が非常に良くなる。

【０００９】また、第一の層がニッケル（Ｎｉ）、白金（Ｐｔ）パラジウム（Ｐｄ）、ロジウム（Ｒｈ）、ルテニウム（Ｒｕ）、オスミウム（Ｏｓ）、イリジウム（Ｉｒ）よりなる群から選択された少なくとも一種を含む金属または合金よりなることを特徴とする。これらの金属または合金はｐ型層と好ましいオーミック接触が得られ、その中でも特に第一の層において、Ｎｉおよび／またはＰｄをｐ層と接する側にすると、さらに好ましいオーミック接触を得ることができる。

【００１０】また、本発明では、第二の層が亜鉛（Ｚｎ）、インジウム（Ｉｎ）、スズ（Ｓｎ）、マグネシウム（Ｍｇ）よりなる群から選択された少なくとも一種を含む酸化物よりなることを特徴とする。具体的にはZnO、In_2O_3、SnO_2、ＩＴＯ（ＩｎとＳｎとの酸化物）、MgO等を挙げることができる。

【００１１】本発明の発光素子において、第一の層、および第二の層を形成するには蒸着、スパッタ等、通常の気相製膜装置を用いることができる。第一の層は透光性の金属薄膜である。金属薄膜を透光性にするには例えば金属薄膜の膜厚の制御により可能である。透光性になる膜厚は金属の種類によっても異なるが、通常０．１μｍ以下の膜厚にすることにより透光性とすることができる。好ましくは５００オングストローム（０．０５μｍ）以下、さらに好ましくは２００オングストローム以下の膜厚にすることにより、第一の層が発光の吸収が少ない優れた透光性を有する。なお透光性とは発光素子の発光波長を電極が透過するという意味であって、必ずしも無色透明を意味するものではない。

【００１２】第一の層はｐ層の電極となる金属で透光性の薄膜を形成できる材料であればどのような材料でも良いが、特にＮｉ、Ｐｔ、Ｐｄ、Ｒｈ、Ｒｕ、Ｏｓ、Ｉｒよりなる群から選択された少なくとも一種を含む金属または合金はｐ層と好ましいオーミック接触が得られ、発光素子の順方向電圧を下げる上で有用である。、その中でも特に、Ｎｉおよび／またはＰｄをｐ層と接する側にすると、窒化物半導体よりなる発光素子の３６０ｎｍ～６５０ｎｍ付近、望ましくは３８０ｎｍ～５６０ｎｍの波長の吸収が少なく、かつオーミック性にも優れているので、最も好ましい。またこの第一層を前記金属の積層構造としてもよい。積層構造の場合、後に電極を熱的ア

ニールで処理すると、電極材料が第一層の中で渾然一体となって合金化した状態となる。

【００１３】第二の層は第一の層の上に形成して、電極全体の抵抗を低くする。そのために第二の層を酸化物を含む透明導電膜とする。酸化物を含む透明導電膜には数々の種類があるが、特に好ましくはＺｎＯ、In_2O_3、SnO_2、ＩＴＯ（ＩｎとＳｎの酸化物）、ＭｇＯ等で示されるＺｎ、Ｉｎ、Ｓｎ、Ｍｇ等の酸化物を含む抵抗の低い透明導電膜を形成することが望ましい。この透明導電膜よりなる第二の層の厚さは特に限定するものではなく、数オングストローム〜数μｍの厚さで形成可能である。

【００１４】本発明の発光素子はＭＯＶＰＥ（有機金属気相成長法）、ＨＤＶＰＥ（ハライド気相成長法）、ＭＢＥ（分子線気相成長法）、ＭＯＭＢＥ（有機金属分子線気相成長法）等の気相成長装置を用いて、基板上に窒化物半導体の結晶を成長、積層することで作成可能である。基板にはサファイア（Al_2O_3）、ＺｎＯ、スピネル（$MgAl_2O_4$）、ＳｉＣ、Ｓｉ、ＧａＮ等が用いられるが、一般的にはサファイア、ＳｉＣが用いられることが多い。積層構造としては、基本的にｎ層の上にｐ層を積層してｐ層が最表面となるように積層して、この最表面のｐ層に電極を形成できる構造とする。具体的にはｐ−ｎ接合を有するヘテロ構造、ｐ−ｉ−ｎ接合を有するヘテロ接合の発光素子等が挙げられる。ｎ型の窒化物半導体は、例えばＳｉ、Ｇｅ、Ｓｅ等のドナー不純物をドープすれば成長可能である。一方、ｐ型の窒化物半導体は、Ｍｇ、Ｚｎ等のII族元素、Ｃ等のアクセプター不純物を窒化物半導体中にドープすることにより成長可能である。例えば、ＭＯＶＰＥ法を用いてアクセプター不純物をドープした窒化物半導体を成長させると、成長後、何の処理をしなくともｐ型特性を示すものもあるが、好ましくは、４００℃以上でアニーリング処理を施すことにより、さらに好ましいｐ型特性を示すようになる。なおｐ型とは、例えばアクセプター不純物をドープした窒化物半導体で、抵抗率が$10^3\Omega\cdot$cm以下を示す半導体をいう。

【００１５】

【作用】図１はｐ層に形成した各種電極の電流電圧特性を示すグラフである。具体的に、ｐ層の上に次に述べる第一の層のみを形成した後、あるいは第一の層と第二の層とを形成した後、４００℃以上でアニールして電極を形成し、同一種類の電極同士の電流電圧特性を測定することにより、その電極のｐ層に対するオーミック性を調べたものである。また、図２は図１に示す透光性電極の透過率を示すグラフである。電極は次の通りである。

【００１６】

Ａ：第一の層にＰｄを４０オングストロームの膜厚で形成した透光性電極。

Ｂ：第一の層にＲｈを４０オングストロームの膜厚で形成した透光性電極

Ｃ：第一の層にＰｄを１０オングストローム、第二の層にＺｎＯを５００オングストロームの膜厚で形成した透光性電極。

Ｄ：第一の層にＰｄを１０オングストローム、第二の層にIn_2O_3を５００オングストロームの膜厚で形成した透光性電極。

Ｅ：第一の層にＮｉを６０オングストローム、第二の層にＡｕを２００オングストロームの膜厚で形成した透光性電極。

【００１７】図１に示すように、Ｐｄ（Ａ）はｐ層と接する側にすると非常に良好なオーミック性を示す。なおＡ線の傾きはＰｄの膜厚が薄くなればなるほど、小さくなる傾向にある。一方、Ｒｈ（Ｂ）は一応オーミック性は示すものの、他のＡ、ＣＤ、Ｅに比べて接触抵抗が大きい。なお他のＲｕ、Ｏｓ、Ｉｒ等の白金族の元素はＢ線と同様の傾向を示したので省略する。次に一層目にＰｄ、二層目にＺｎＯを形成した電極（Ｃ）、及び一層目にＰｄ、二層目にIn_2O_3を形成した電極（Ｄ）も良好なオーミック接触を示している。この傾向は第二層目をＩＴＯ、SnO_2またはＭｇＯとしても同様であったので省略する。また一層目にＮｉ、二層目にＡｕを形成した電極（Ｅ）は良好なオーミック接触を示しているが透過率が悪い。これは後に述べる。なおオーミック性に関しては第一層目にＮｉ、Ｐｔを形成した電極もＥ線と同様の傾向を示したので省略する。

【００１８】また図２は各電極の透過率を示すものであるが、従来のＮｉ−Ａｕを含む電極（Ｅ）は窒化物半導体発光素子の発光の特徴である紫色〜緑色領域にかけての透過率が悪い。これに対し、本発明の発光素子に係る電極Ｃ、Ｄの透過率はＥに比べて非常に優れているので、発光素子の外部量子効率を向上させることができる。また、第一層目にのみ他の白金族の元素Ｐｔ、Ｒｕ、Ｏｓ、Ｉｒ等の元素よりなる透光性電極はＡ，Ｂ線と類似した透過率を示すので省略する。

【００１９】ｐ層を最表面とする発光素子では、ｐ層に形成した電極が発光をさえぎらなければ、発光素子の外部量子効率が向上する。そこで、ｐ層の表面に、透過率のよい透光性の金属薄膜よりなる第一の層と、透過率の良い酸化物を含む透明導電膜よりなる第二の層とからなる電極を形成することにより、発光素子の外部量子効率は向上する。

【００２０】さらに、第一の層の膜厚が５００オングストローム以下であると、透光性の良い電極としての第一の層を形成することができるが、第一の層の膜厚を次第に薄くすることにより、電極のｐ層に対するシーズ抵抗が大きくなる傾向にある。本発明では透明な導電膜である第二の層を、第一の層の上に形成していることにより、全体としての電極の厚さが厚くなって、抵抗が大きくなるのを防止できる。しかも、電極全体としては透光

性を保ったままであるので、発光は効率よく外部へ取り出される。

【００２１】さらに、第一の層にＮｉ、Ｐｔ、Ｐｄ、Ｒｈ、Ｒｕ、Ｏｓ、Ｉｒよりなる群から選択された少なくとも一種を含む金属または合金とすることにより、膜厚を薄くした状態においてもｐ層と好ましいオーミックが得られるために、発光素子のＶｆが下がり、発光効率に優れた素子を実現できる。また窒化物半導体発光素子が特徴とする紫〜緑色波長域での透過率がよい。

【００２２】また、第二の層にＺｎ、Ｉｎ、Ｓｎ、Ｍｇよりなる群から選択された少なくとも一種を含む導電性の酸化物薄膜は前記のように紫〜緑色波長域での透過率が良く、さらに、第一の層の膜厚を薄くしても、この第二の層があるために電極の抵抗が上がらないという利点を有する。

【００２３】

【実施例】以下、図面を基に本発明の発光素子の一実施例について説明する。図３は本発明の発光素子をｐ層の電極側から見た平面図であり、図４は図３の発光素子を図に示す一点鎖線で切断した際の構造を示す模式的な断面図である。

【００２４】［実施例１］ＭＯＶＰＥ反応装置を用い、２インチφのサファイア基板１の上にＧａＮよりなるバッファ層２を２００オングストローム、Ｓｉドープｎ型ＧａＮよりなるｎ型コンタクト層３を４μｍ、ノンドープ$In_{0.2}Ga_{0.8}N$よりなる単一量子井戸構造の活性層４を３０オングストローム、Ｍｇドープｐ型$Al_{0.1}Ga_{0.9}N$よりなるｐ型クラッド層５を０．２μｍ、Ｍｇドープｐ型ＧａＮよりなるｐ型コンタクト層６を０．５μｍの膜厚で順に成長させる。

【００２５】さらにウェーハーを反応容器内において、窒素雰囲気中で６００℃でアニーリングして、ｐ層５、６をさらに低抵抗化する。アニーリング後、ウェーハを反応容器から取り出し、最上層のｐ型ＧａＮの表面に所定の形状のマスクを形成し、エッチング装置でマスクの上からエッチングを行い、図２に示すようにｎ型コンタクト層３の一部を露出させる。

【００２６】次に、ｐ層の上のマスクを除去し、最上層のｐ型ＧａＮ層のほぼ全面に第一の層１０として、Ｐｄを２０オングストロームの膜厚で蒸着する。蒸着後の第一の層は明らかに透光性となっており、サファイア基板１まで透けて観測できた。このように第一の層を、露出したｐ層のほぼ全面に形成することにより、電流をｐ層全体に均一に広げることができ、しかも透光性であるので、電極側を発光観測面とできる。

【００２７】第一の層１０形成後、第一の層の隅部にＡｕとＮｉを含むボンディング用のパッド電極１３を２μｍの膜厚で形成する。なおこのパッド電極１３は透光性ではない。

【００２８】パッド電極１３形成後、第一の層１０の上にＩＴＯよりなる第二の層１１を５００オングストロームの膜厚で蒸着する。

【００２９】パッド電極１３を形成した後、露出したｎ層にＴｉとＡｌとを含むｎ電極１４を２μｍの膜厚で形成し、最後にアニール装置で４００℃以上で熱処理を施し、電極を合金化させる。なおアニールによりｐ層の第一の層１０と第二の層１１とからなる透光性の電極は合金化して渾然一体となった状態となっているので、図１では、あえて最表面の電極を第二の層１１と示さず、第一の層＋第二の層という意味で１０＋１１という符号で示している。

【００３０】以上のようにして、ｎ型コンタクト層３とｐ層コンタクト層６とに電極を形成したウェーハを、３５０μｍ角のチップ状に切断し、その発光チップのサファイア基板側１をリードフレームと接着し、ワイヤーボンドし、エポキシ樹脂でモールドしてＬＥＤ素子としたところ、Ｉｆ（順方向電流）２０ｍＡにおいて、Ｖｆ（順方向電圧）３．４Ｖ、発光波長４６０ｎｍであり、発光出力は、従来のＮｉとＡｕを含む透光性のｐ電極を有する同構造のＬＥＤよりも、約３０％高かった。

【００３１】［実施例２］実施例１において、第一の層１０にＮｉを２０オングストローム、第二の層１１にIn_2O_3を５００オングストロームの膜厚で形成する他は、実施例１と同様にしてＬＥＤ素子を得たところ、Ｉｆ２０ｍＡにおいて、Ｖｆ３．５Ｖで発光出力は実施例１のものとほぼ同等であった。

【００３２】［実施例３］実施例１において、第一の層１０にＰｄを１０オングストローム、Ｎｉを１０オングストローム積層し、第二の層１１にSnO_2を用いる他は実施例１と同様にしてＬＥＤ素子を得たところ、Ｉｆ２０ｍＡにおいて、Ｖｆ３．４Ｖ、発光出力も実施例１のものとほぼ同等であった。

【００３３】［実施例４］実施例１において、第一の層１０にＰｄを１０オングストローム、Ｐｔを１０オングストローム積層し、第二の層１１にＺｎＯを用いる他は実施例１と同様にしてＬＥＤ素子を得たところ、Ｉｆ２０ｍＡにおいて、Ｖｆ３．５Ｖ、発光出力も実施例１のものとほぼ同等であった。

【００３４】［実施例５］実施例１において、第一の層１０にＰｄを１０オングストローム、Ｒｈを１０オングストローム積層し、第二の層１１にＭｇＯを用いる他は実施例１と同様にしてＬＥＤ素子を得たところ、Ｉｆ２０ｍＡにおいて、Ｖｆ３．５Ｖ、発光出力も実施例１のものとほぼ同等であった。

【００３５】［実施例６］実施例１において、第一の層１０にＰｄを１０オングストローム、Ｒｕを１０オングストローム積層し、第二の層１１にIn_2O_3を用いる他は実施例１と同様にしてＬＥＤ素子を得たところ、Ｉｆ２０ｍＡにおいて、Ｖｆ３．５Ｖ、発光出力も実施例１のものとほぼ同等であった。

【００３６】［実施例７］実施例１において、第一の層１０の膜厚を２００オングストロームとする他は実施例１と同様にして、ＬＥＤ素子を得たところ、Ｉｆ２０ｍＡにおいて、Ｖｆ３．４Ｖであったが、第一の層の透光性がやや失われたため、発光出力は実施例１のものに比べて２０％程低下した。

【００３７】

【発明の効果】以上説明したように本発明の発光素子は、ｐ層の表面に形成して、活性層の発光を有効に外部に取り出すことができる。しかも電極がｐ層とのオーミック性にも優れているため、Ｖｆが低い実用的な発光素子を実現できる。本発明の発光素子を例えばフルカラーＬＥＤディスプレイ、ＬＥＤ信号機、道路情報表示板等のＬＥＤデバイスに使用すると、低消費電力で明るいデバイスが実現でき、その産業上の利用価値は大である。

【図面の簡単な説明】

【図１】　ｐ層に形成した各種電極の電流電圧特性を示＊

＊す図。

【図２】　ｐ層に形成する各種電極の各波長に対する透過率を示す図。

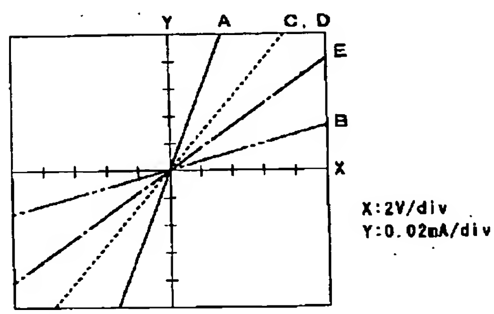
【図３】　本発明の一実施例に係る発光素子の電極形状を示す平面図。

【図４】　図１の発光素子の構造を示す模式断面図

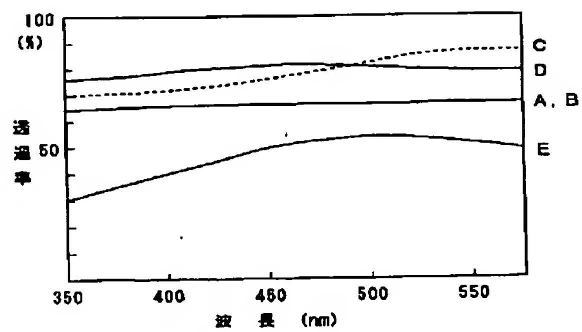
【符号の説明】

１・・・・サファイア基板
２・・・・バッファ層
３・・・・ｎ型コンタクト層
４・・・・活性層
５・・・・ｐ型クラッド層
６・・・・ｐ型コンタクト層
１０・・・・第一の層
１１・・・・第二の層
１３・・・・パッド電極
１４・・・・ｎ電極

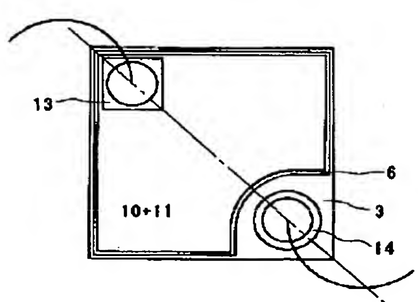
【図１】



【図２】



【図３】



【図４】